Contemporary and Historical Descriptions of the Vegetation of Brundee and Saltwater Swamps on the Lower Shoalhaven River Floodplain, Southeastern Australia

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Coastal floodplains are functionally important and highly endangered ecosystems in southeastern Australia, which have a long history of exploitation and environmental modification. In this study, we undertook a systematic survey of contemporary vegetation in two recently established nature reserves on the south coast of New South Wales and investigated historical records of the vegetation and environment to infer likely changes since European settlement. An analysis of floristic samples showed that the present-day floodplain vegetation includes a mosaic of woodlands, forests and saltmarsh/reedland (five communities) that contrast markedly in species composition and structure to eucalypt forests that occupy the surrounding hills (two communities). One hundred and forty-nine plant species were recorded in 24 0.04 ha samples within the reserves, with Poacaeae and Cyperaceae represented by the most species on the floodplain. Some parts of the floodplain contain substantial weed infestations, while other parts of the floodplain are largely free of weeds. The vegetation underwent a series of changes since the first recorded observations in 1805. At that time the floodplain included a mosaic of woodland, grassland and reedland. Native grassland now appears to be extinct as a result of subsequent clearing, intensive cattle grazing, pasture improvement and changes to drainage. A network of drains, initially constructed around 1900 and further developed in the 1960s, resulted in soil oxidation. This may have made the floodplain soils more suitable for woody plant species, but recruitment has been largely prevented by intensive cattle grazing. A recent expansion of *Casuarina* and *Melaleuca* scrub and forest is evident within the nature reserves since their dedication and exclusion of livestock in 2001, but not on adjoining properties where intensive cattle grazing continues. We conclude that the reserves include important samples of remnant floodplain vegetation and that the vegetation is in a continuing state of flux regulated by changing flood and tidal regimes and grazing regimes.

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KEYWORDS: coastal wetlands, Endangered Ecological Communities, European impact, floodplain, Shoalhaven River, vegetation change, vegetation classification, vegetation history.

INTRODUCTION

Coastal wetlands are functionally important ecosystems. They are significant carbon sinks, resource-rich repositories of moisture and nutrients, habitats for highly specialised plant life and important breeding grounds for wetland-dependent fauna including birds, frogs, fish, crustacea, molluscs and other invertebrates.

Coastal floodplains are perhaps the most endangered and heavily modified ecosystems in southeastern Australia (Keith 2004, Keith and Scott 2005). The present status and parlous future of these remnants is recognised in the listing of six Endangered Ecological Communities under the *Threatened Species Conservation Act (1995)* in New South Wales. Complex interactions between multiple processes has transformed temperate coastal floodplains from natural systems to intensely managed human landscapes. These processes include clearing of native vegetation, intensive grazing by domestic cattle, pasture improvement and cultivation, changes to water regimes (water table depth, floods, tides), particularly through construction of drains and tidal gates, changes in soil chemistry and structure, and invasions of alien plant and animal species. Collectively, these processes have had a range of adverse impacts on the ecological functions of floodplains. For example, coastal floodplain soils often have high concentrations of sulfur, which accumulated during the deposition of marine sediments in the early stage of floodplain development. Drainage works or other earthworks in the swamps, expose their soils to oxidation, liberating sulphuric acid into the soil solution (Johnston et al. 2003). As well as being toxic to plants and animals, sulphuric acid leaches minerals that would otherwise be fixed in the soil, including iron, aluminium and magnesium. Thus, rapid drainage of swamps after rainfall can cause high concentrations of acid and dissolved metal ions in drains and estuaries, killing fish and other animals dependent on the estuaries. The decline of aquatic life in acid-affected swamps also has impacts on the use of these areas by other water-dependent fauna, including waterbirds.

Despite the intensity of past and present land uses, many of the coastal floodplains still support fragments of native vegetation, albeit in a highly modified form (Keith 2004). These are maintained in a state of flux in response to continuing changes in land use, particularly water management, grazing and cropping. Under the influences of global climate change, the remaining native vegetation is likely to become even less stable in the future. Vegetation changes have profound effects on the ecological functions of the floodplains. For example, projected increases in atmospheric CO_2 concentrations, rising temperatures and projected declines in precipitation and flood frequency are predicted to accelerate the release of carbon from wetland sediments (Gorham 1991, Freeman et al. 2004) and drive structural change in habitats of specialised organisms (Hughes 2003).

At present, the mechanisms that regulate the direction and rates of vegetation change on coastal floodplains are poorly understood. The experimental studies needed to elucidate these mechanisms require baseline data as context for interpreting future responses to environmental change. While comprehensive surveys have been carried out in wetlands on some subtropical latitudes (Pressey 1989a, b, Pressey and Griffith 1992), floodplains of more temperate latitudes have been comparatively neglected. On the Shoalhaven River floodplain 120 km south of Sydney, conservation reserves have been established on parts of two floodplain wetlands, which provide important reference areas for research on wetland dynamics in response to changes in both climate and land use. The aims of this study were to describe and map present-day vegetation of the reserves by gathering baseline data from the field, and to describe past states of the vegetation by reviewing historical information from the recent past and early European times.

METHODS

Study area

Brundee Swamp and Saltwater Swamp are located about 7 km south-east of Nowra (latitude 34°55'S, longitude 150°39'E) on the edge of the broad, lowland floodplain of the Crookhaven River. Brundee Swamp is on the upper floodplain of the Crookhaven River, which subsequently runs through Saltwater Swamp before entering the ocean close to the mouth of the Shoalhaven River. The northern parts of Brundee and Saltwater Swamps are freehold land and have been used for grazing and associated cropping for many years (Dalmazzo et al. 2000). Nature reserves were established in southern parts of the two swamps in January 2001 on former Crown land that was subject to permissive occupancies for cattle grazing by adjoining landholders. Brundee Swamp covers an area of approximately 600 ha, of which 230 ha are included within the nature reserve. Saltwater Swamp covers approximately 480 ha, of which 215 ha are included within the nature reserve. The two nature reserves are separated by a distance of about 1 km, comprising partially cleared freehold land, which occupies a low rise above the floodplain. To the south and west of the reserves, the floodplain rises gradually into low forested hills of siltstone and sandstone, which are partly freehold and partly within Currambene State Forest.

Brundee and Saltwater Swamps are large, low-lying, shallow, fresh to brackish wetlands mostly at or below Mean Sea Level (±1.0 m). Some small areas are inundated semi-permanently, while large areas of both swamps are inundated periodically and are without surface water for most of the time (Dalmazzo et al. 2000). Each swamp has a small catchment of less than 2 000 – 3 000 ha. The swamps apparently formed as a result of deposition of marine, estuarine and fluvial sediments, which infilled old coastal lagoons as sea levels rose at the end of the last glaciation (Dalmazzo et al. 2000).

Field Sampling

Floristic composition and vegetation structure were sampled at 21 sites within the Brundee and Saltwater Swamp nature reserves. In addition, four samples were obtained from a previous survey project (Tindall et al. 2004), including three within the reserves and one nearby. The sites were located to cover a range of landforms, structural forms and geographic locations within the study area including forest, scrub and sedgelands on the floodplain, forests on the margins of the floodplain, and forests on low hills and slopes above the floodplain.

Fieldwork was carried out during 16-17 February 2006. Vegetation sampling methods were identical to those used by Tindall et al. (2004) and Gellie (2005). A global positioning system was used to record the location and elevation of each survey site Tape measures were used to mark out survey quadrats of 0.04 ha. These quadrats were square (20 x 20 m), except where different dimensions were required to ensure that landform and soils were reasonably homogeneous within the plot (for example an 8 x 50 m quadrat was used along a drainage feature).

All vascular plant species rooted within or overhanging the quadrat were recorded and assigned a cover/abundance score using a modified Braun - Blanquet scale (Poore 1955) as follows: 1- Rare, one or few individuals present and cover < 5%; 2- uncommon and cover < 5%; 3- common and cover < 5%; 4- very abundant and cover < 5% or 5% ≤ cover < 20%; 5- 20% ≤ cover <50%; 6- 50% ≤ cover <75%; 7- 75% ≤ cover ≤ 100%.

The height range and projected foliage cover were estimated for all vegetation strata recognisable at the site (e.g. tree, small tree, shrub, groundcover). At the centre of the quadrat, a compass and clinometer were used to measure the slope, aspect and horizon elevations at compass bearings of 0, 45, 90, 135, 180, 225, 270 and 315°. Soils were examined by hand-texturing and notes made on colour, texture, moisture content and depth. Evidence of outcropping rock, erosion, weed invasion, logging, soil disturbance or recent fire was noted.

All native and exotic vascular plant species were recorded. Plant species that could not be identified in the field were collected for later identification. Where necessary, collections were sent for identification to the National Herbarium of NSW. Nomenclature was standardised to follow Harden (1990 - 2002) and Flora Online (http://plantnet.rbgsyd.gov.au).

To allow for ongoing monitoring of the plots, a steel star post marked with a fluorescent green top and a uniquely numbered stainless steel tag was located at the north eastern corner of each quadrat. A photopoint was established at each site framing the corner post from a bearing that was recorded on the field data sheet. An indicative assessment of fuel loads was made at each site based on the method for fine fuels and total fuel load described in the Department of Environment and Conservation's Incident Field Handbook (pp 24 - 25).

To assess spatial variation in growth stages within each woody vegetation type, the angle count (Bitterlich) method was used to estimate stand basal area at each quadrat. The Bitterlich method uses an angle gauge, a stick 1 m in length with a 20 mm cross piece at one end, to assess all the trees around a central sampling point (Mueller-Dombois and Ellenberg 1974; Carron 1968). The operator stands at the sampling point, sights along the stick to the cross piece at the far end, and counts the number of trees with diameter at breast height larger than, or equal to, the angle indicated by the cross-piece. Counts were tallied by assigning a full point to trees larger than the cross piece and a half point score to trees equal to the cross piece. With a 20 mm cross piece on a stick of 1 m (ie a ratio of 1:50), the Bitterlich count approximates the basal area of trees in the stand in square metres per hectare.

Data analysis and description of Plant Communities

A multivariate analysis of native species composition data from the plots was carried out to develop a classification of plant communities in the two reserves. A data matrix was first assembled from all available data, including the 21 plots recorded in this survey and four plots recorded previously in and around the reserves during the P5MA survey (Tindall et al. 2004). All exotic species were excluded from the data matrix so that the classification was based on native species composition. Specimens that could not be identified to species level were also omitted from the analysis. Compositional dissimilarity among samples was computed on unstandardised data using a symmetric form of the Kulczynski coefficient (Belbin 1994). Hierarchical agglomerative clustering was carried out using a flexible unweighted pair group arithmetic averaging strategy with no adjacency constraint and $\beta = -0.1$.

To assist interpretation of site groupings defined in the cluster analysis, the 25 samples from Brundee and Saltwater Swamps were added to a larger set of samples compiled by Tindall et al. (2004) from the lower Shoalhaven district. This larger data set was analysed using the same methods as those described above. The correspondence between the site groups for Brundee and Saltwater Swamps and existing communities defined by Tindall et al. (2004) was assessed by cross-referencing group membership for the sites between the two classifications. This allowed each new site from Brundee and Saltwater Swamps to be assigned to one of the P5MA communities. These interpretations were verified by assessing the species list for each site against the list of diagnostic species for the corresponding community described by Tindall et al. (2004).

Map preparation

Existing vegetation boundaries on the P5MA vegetation map (Tindall et al. 2004) were updated by stereoscopic aerial photo interpretation (API) of colour photography 1:15 000 scale flown in January 1996. Boundaries were further adjusted on-screen using an orthorectified digital aerial photograph flown in 2001. The photography was interpreted to delineate all patches of native vegetation larger than one hectare in size. In some cases, it was possible to map additional patches that were smaller than one hectare. Woody vegetation was mapped where crown cover was $\geq$ 5%. Interpretation of boundaries was informed by location of sample sites and additional field reconnaissance.

Vegetation and management history

We reviewed evidence of changes to the local floodplain environment and its vegetation from a number of different sources. These included surveyors's maps and reports for the Shoalhaven floodplain from the Land Property Information Service; historical articles; reports and journal articles on local environmental studies; and aerial photographs of the Brundee and Saltwater Swamps flown at two recent dates (1996 and 2001). We interpreted information from these sources to reconstruct likely characteristics of historical water regimes, soils and vegetation of the local floodplain.

RESULTS

Vegetation Classification

The 25 vegetation samples were classified into seven groups on the basis of similarities in species composition (Fig. 1). Each of these plant assemblages was referrable to communities described previously by Tindall et al. (2004). Eucalypt-dominated communities were segregated in the dendrogram from the remainder of the samples. Eucalypts were generally confined to the margins of the floodplain and the surrounding hills, while the floodplain itself was characterised by a mosaic of forested wetlands dominated by non-eucalypt tree genera and treeless wetlands.

Description of Plant Communities

A local synopsis of the seven communities for

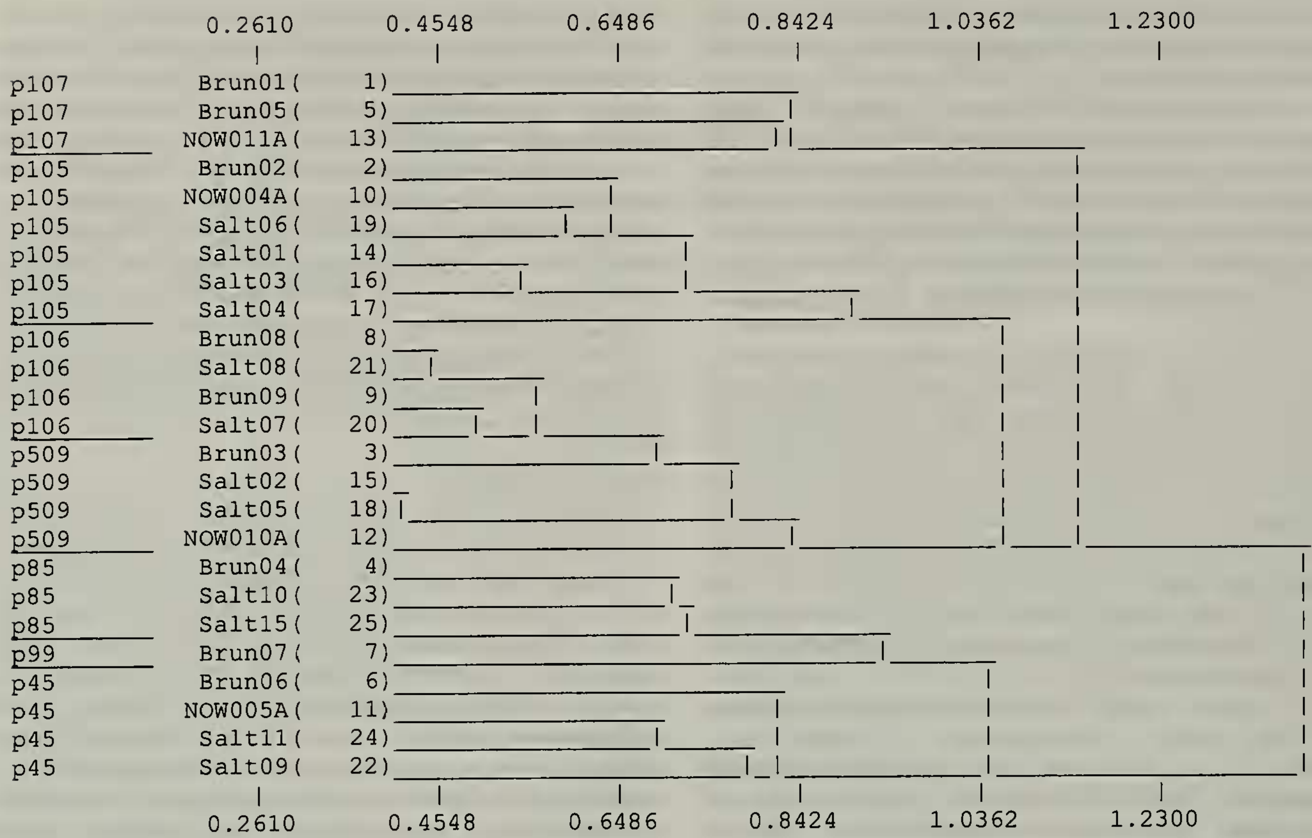

Figure 1. Dendrogram showing the compositional relationships of 25 vegetation samples and the plant community to which each sample was allocated (left-hand column). Scales at the top and bottom of the dendrogram show Kulzcynski ultra-metric dissimilarity values.

Brundee and Saltwater Swamp Nature Reserves is given below. Their mapped distributions are shown in Fig. 2. The most extensive communities within the reserves are Estuarine Fringe Forest and Floodplain Swamp Forest, with Estuarine Creekflat Scrub and Currambene Lowland Forest the next most abundant communities (Table 1). The other three communities are not common within the reserves.

Tozer et al. (2006) provide more general descriptions for each of the seven mapped communities across a larger region between Sydney and the Victorian border. The codes for each map unit follow those of Tozer et al. (2006), in which capital letters represent abbreviations of structural formations described by Keith (2004). These include: FOW Forested Wetlands; SL Saline Wetlands, DSF Dry Sclerophyll Forests, and WSF Wet Sclerophyll Forests.

As of 31 December 2005, three Endangered Ecological Communities (EECs) listed under the NSW *Threatened Species Conservation Act* (TSC Act 1995) occur in Brundee Swamp and Saltwater Swamp NRs. The inferred relationships between each of these EECs and the plant communities described and mapped below are given in Table 2. A fourth EEC, Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and Southeast Corner bioregions, occurs nearby but is not currently mapped within the reserves. No ecological communities currently listed as Endangered under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act 1999) occur in the reserves.

Floodplain Swamp Forest (FOW p105)

Floodplain Swamp Forest (Fig. 3) within the reserves is characterised by a typically dense to open canopy dominated by *Casuarina glauca* with trees or shrubs of *Melaleuca ericifolia* (or occasionally *M. styphelioides*) in comparatively lower abundance. The understorey generally lacks woody plants other than sparse juvenile individuals of the canopy species. Vines of *Parsonsia straminea* occur occasionally, either as scramblers at ground level or ascending stems of canopy trees. The groundcover comprises an open cover of sedges, grasses and forbs, including *Entolasia marginata, Juncus kraussi* subsp. *australasicus*, *Carex appressa* and *Cyperus polystachyos*, with *Commelina cyanea*, *Lobelia anceps*, *Alternanthera denticulata* and *Senecio hispidulus* var. *hispidulus*, which are dispersed within a dense cover of leaf litter from the canopy. Patches of *Phragmites australis* may occur in the understorey where the water table is more frequently close to the surface (Fig. 4).

Floodplain Swamp Forest has been recorded and mapped primarily around the eastern and western margins of Brundee Swamp (from which one site was recorded – Brun02) and a large patch covering the central and eastern portions of Saltwater Swamp (from which the remaining five sites were recorded). These are raised areas of the floodplain that are likely to experience lower levels of salinity in

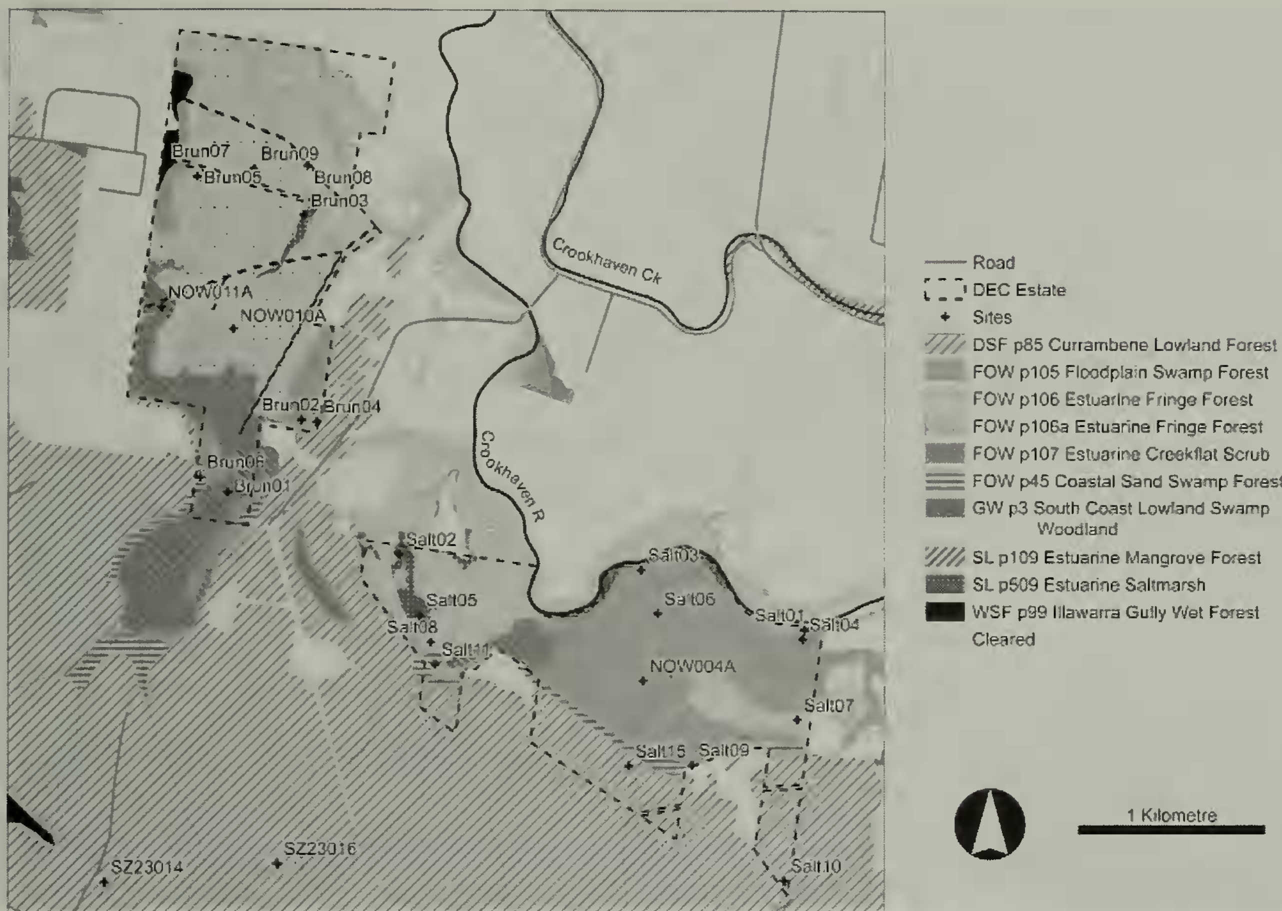

Figure 2. Vegetation map of Brundee Swamp, Saltwater Swamp and surrounding areas.

Table 1. Estimated areas of plant communities within Brundee Swamp NR and Saltwater Swamp NR.

Community	Estimated area in Brundee Swamp NR (ha)	Estimated area in Saltwater Swamp NR (ha)	Total (ha)
Floodplain Swamp Forest (FOW p105)	16.4	98.4	114.8
Estuarine Fringe Forest (FOW p106)	49.8	46.9	96.8
Estuarine Fringe Forest regenerating (FOW p106a)	119.0		119.0
Estuarine Creekflat Scrub (FOW p107)	32.9	9.1	41.9
Estuarine Saltmarsh (SL p509)	2.1	9.2	11.3
Coastal Sand Swamp Forest (FOW p45)	1.6	8.6	10.2
Currambene Lowland Forest (DSF p85)	1.2	41.5	42.8
Illawarra Gully Wet Forest (WSF p99)	4.4		4.4
Water		0.5	0.5
Total	**227.3**	**214.2**	**441.5**

their groundwater than stands of Estuarine Fringe Forest (FOW p106), which occur on lower parts of the floodplain and in local depressions. Much of the eastern two-thirds of Saltwater Swamp NR has been mapped as FOW p105. Within this area, small depressions with more saline influence may support (unmapped) patches of FOW p106.

Estuarine Fringe Forest (FOW p106)

Estuarine Fringe Forest (Fig. 5) within the

Table 2. Endangered Ecological Communities (*Threatened Species Conservation Act 1995*) found within Brundee Swamp and Saltwater Swamp Nature Reserves and their relationship to map units defined in this study. (The legal definitions of EECs are provided by the Final Determinations under the TSC Act. Diagnoses as to whether any particular area of vegetation constitutes an EEC should be based on field inspection and comparison with the relevant Final Determination.)

Endangered Ecological Communities listed under the TSC Act 1995	Corresponding Map Unit	Relationship
Coastal saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions	Estuarine Saltmarsh (SL p509)	SL p509 is included within this broader EEC
Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregions	Floodplain Swamp Forest (FOW p105) + Estuarine Fringe Forest (FOW p106) + Estuarine Creekflat Scrub (FOW p107)	FOW p105, FOW p106 and FOW p107 are included within the broader EEC
Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (incorporating the formerly listed Sydney Coastal Estuary Swamp Forest Complex in the Sydney Basin Bioregion)	Coastal Sand Swamp Forest (FOW p45)	FOW p45 is included within the broader EEC

reserves is characterised by a typically dense canopy dominated by *Casuarina glauca* with occasional trees or shrubs of *Melaleuca ericifolia*. The understorey generally lacks woody plants other than sparse juvenile individuals of the canopy species, while vines are generally absent. The groundcover typically includes a prominent stratum of tussock sedges, particularly *Juncus kraussi* subsp. *australasicus*, with a groundcover of succulent forbs, *Selliera radicans* and *Sarcocornia quinquefaria*, and other forbs, *Commelina cyanea* and *Alternanthera denticulata*, which are typically dispersed amongst a dense cover of leaf litter from the canopy. In the Brundee-Saltwater area, Estuarine Fringe Forest has a very similar tree canopy to Floodplain Swamp Forest, although *Melaleuca styphelioides* does not occur in the former. The principal differences are in the understorey, with Estuarine Fringe Forest (FOW p106) generally having lower overall diversity, no vines and a greater abundance and diversity of succulent forbs than Floodplain Swamp Forest (FOW p105).

Estuarine Fringe Forest has been recorded and mapped primarily in low-lying areas in the northern and central portions of Brundee Swamp NR (Brun08, Brun09) and the western portion of Saltwater Swamp NR (Salt08), although a patch also occurs within a shallow depression in the east of this reserve (Salt07). The lower areas of the floodplain that support Estuarine Fringe Forest are likely to experience higher levels of salinity in their groundwater (due to greater exposure to tidal inundation) than stands of Floodplain Swamp Forest (FOW p105), which occur on slightly more elevated parts of the floodplain. Elsewhere in the Sydney-South Coast region, small patches of Estuarine Fringe Forest are scattered along the coast to both the north and south, "fringing the high tide mark on the margins of tidal lakes, lagoons, inlets and river estuaries" (Tindall et al. 2004). While the mapped distribution in the Brundee-Saltwater area appears atypical, it may reflect residual salinity from former tidal flooding patterns, which have since been modified by drainage works. It is also possible that similar habitats to those supporting Estuarine Fringe Forest in the Brundee-Saltwater area have been destroyed elsewhere.

In Brundee Swamp NR, a large area of Estuarine Fringe Forest (FOW p106) is currently an open sedgeland with scattered individuals of *Casuarina glauca*, which are usually immature (Fig. 6). This area is mapped as p106a to distinguish the difference in growth stage from the more typical form of the community (mapped as p106), which has a much denser and taller canopy of mature *Casuarina glauca*. It appears that the woody component of the community is re-establishing in this area following the exclusion of livestock after the reserve was declared in 2001. The difference in tree abundance is reflected in the Stand Basal Area at Breast Height for site Brun09 (1 m^2/ha) compared to Brun08 (33 m^2/ha). Sites within the area mapped as p106a also have

Figure 3. A typical stand of Floodplain Swamp Forest showing *Casuarina glauca* (background) with *Melaleuca ericifolia* (foreground) and a sparse groundcover amongst a dense layer of compressed leaf litter.

a higher abundance and proportion of exotic species than sites within the area mapped as p106, reflecting the association between weed invasion and livestock grazing.

Estuarine Creekflat Scrub (FOW p107)

Estuarine Creekflat Scrub (Fig. 7) within the reserves is characterised by a typically dense canopy dominated by *Melaleuca ericifolia* with occasional trees of *Casuarina glauca*. The understorey generally lacks woody plants other than juvenile individuals of the canopy species. Vines of *Parsonsia straminea* occur occasionally, either as scramblers at ground level or ascending stems of canopy trees or shrubs. The groundcover is highly variable, with tall patches of *Phragmites australis* and *Gahnia clarkei*, patches of tussock sedges including *Juncus* spp., *Carex appressa* and *Cyperus lucidus*, and a scattered cover of forbs including *Centella asiatica*, *Senecio minimus*, and *Selliera radicans*, interspersed with large patches of bare ground covered by copious leaf litter from the canopy.

Estuarine Creekflat Scrub has been recorded and mapped primarily in a drainage depression at the southern end of the Brundee Swamp floodplain (from which two of the three sites were recorded), although smaller stands are also mapped in the south-eastern and south-western margins of Saltwater Swamp. The third site (Brun05) was recorded in the mid-western portion of Brundee Swamp NR. This area has been heavily affected by clearing, grazing and drainage changes, and is currently mapped as a degraded area of Estuarine Fringe Forest. However, the floristic composition of Brun05 suggests that parts of this area could include some degraded stands of Estuarine Creekflat Scrub.

Estuarine Saltmarsh (SL 509)

Estuarine Saltmarsh (Fig. 8) within the reserves is essentially treeless, although it may have *Casuarina glauca,* or rarely *Melaleuca ericifolia,* present as scattered shrubs. Its most prominent feature is a relatively dense, but variable cover of the tussock rush, *Juncus kraussi* subsp. *australasicus.* In gaps between dense patches of this rush, there is a more-or-less continuous cover of succulent forbs, *Selliera radicans, Sarcocornia quinquefaria* and *Lobelia anceps*, and the grass, *Lachnagrostis filiformis.* Patches of bare ground are limited. Estuarine Saltmarsh (SL p509) may be difficult to distinguish from regenerating stands of Estuarine Fringe Forest (mapped as FOW p106a), although saltmarsh typically occurs in local depressions where soil conditions are more saline. These two communities may be in a continuous state of flux related to changes in water and salinity regimes.

Estuarine Saltmarsh has been recorded and mapped primarily in low-lying patches in the north-

Figure 4. A variant of Floodplain Swamp Forest at Salt03 (Saltwater Swamp NR) showing a patch of *Phragmites australis* beneath a canopy of *Casuarina glauca.*

western section of Saltwater Swamp NR (Salt02, Salt05). In Brundee Swamp, a restricted area of saltmarsh has been recorded and mapped along a brackish drainage channel in the eastern part of the reserve (Brun03, NOW10A). However, the small occurrences of saltmarsh in Brundee Swamp are uncertain, given the structural and floristic resemblance to regenerating Estuarine Fringe Forest (FOW p106a), which occurs adjacent to the putative stands of saltmarsh and across large areas of Brundee Swamp.

Elsewhere in the Sydney-South Coast region, Estuarine Saltmarsh is scattered along the coast on mudflats associated with estuaries in locations where there is occasional tidal inundation. Collectively, these saltmarshes encompass a diverse group of assemblages (Adam et al. 1988). Some of these assemblages may form fine-scale mosaics within a single stand of saltmarsh, possibly in response to local variations in soil salinity and tidal inundation regimes. The Estuarine Saltmarsh in the Brundee-Saltwater area is comparatively uniform in composition and probably samples the lower part of the range of variation in soil salinity.

Coastal Sand Swamp Forest (FOW p45)

Coastal Sand Swamp Forest (Fig. 9) within the reserves is characterised by a relatively dense tree canopy dominated by *Eucalyptus robusta,* with occasional trees of *E. botryoides* or *E. longifolia* at the margins of stands. A diverse subcanopy is dominated by *Melaleuca ericifolia,* with *M. styphelioides, M. decora, M. lineariifolia* and *Casuarina glauca* occurring less frequently and occasionally equalling the eucalypt canopy in height. *Cymbidium suave* occurs sporadically on the tree branches. The understorey includes varying densities of juvenile individuals of the canopy species, occasional clumps of the large sedge, *Gahnia clarkei,* and scattered shrubs of various species. Occasional vines of *Parsonsia straminea, Marsdenia rostrata* and *Kennedia rubicunda* ascend tree trunks, festoon shrubs or scramble along the ground. Clumps of ferns, *Hypolepis muelleri* and *Pteridium esculentum,* punctuate a continuous groundcover of grasses, including *Entolasia marginata, E. stricta, Imperata cylindrica, Microlaena stipoides, Echinopogon ovatus* and *Oplismenus imbecillus,* and forbs including *Centella asiatica, Dichondra repens, Opercularia diphylla, Pratia purpurascens, Senecio hispidulus* var. *hispidulus* and *Veronica plebeia.* Other frequent groundcover species include *Adiantum aethiopicum* and the twiners *Cassytha pubescens* and *Glycine* spp. Coastal Sand Swamp Forest is the most floristically rich and structurally complex vegetation type within the reserves, and is therefore likely to be important fauna habitat.

Coastal Sand Swamp Forest has been recorded and mapped around the southern margins of both Brundee (Brun06) and Saltwater (Salt09, Salt11) Swamps. Small patches have also been mapped and recorded to the west of Brundee Swamp (NOW05A),

Figure 5. Estuarine Fringe Forest at Salt08 (Saltwater Swamp NR) showing a tree canopy of *Casuarina glauca* over scattered tussocks of *Juncus kraussi* subsp. *australasicus*, and patches of *Selliera radicans* amongst copious *Casuarina* leaf litter.

outside the reserve. The stands in the reserves are restricted to narrow ecotones with poorly drained, humic sandy soils where the margins of the floodplain receive freshwater runoff from the toeslopes of the surrounding hills. These stands are only partly included within the reserve boundaries. The stands associated with Brundee Swamp are structurally simpler than those associated with Saltwater Swamp, and this probably reflects the influence of past management regimes (Fig. 10). The mapped areas of Coastal Sand Swamp Forest, outside the reserve, to the west of Brundee Swamp are associated with shallow drainage lines in slightly more elevated terrain.

Elsewhere in the Sydney-South Coast region, Coastal Sand Swamp Forest occurs in small stands associated with poorly drained swales and drainage lines on coastal sandplains. The main areas of occurrence are around Botany and Jervis Bays, though little of the former remains (Tindall et al. 2004). Small stands of the community are also associated with the margins of Coomonderry Swamp. The stands in the Brundee-Saltwater area are unusual in the sense that they are associated with the margins of a floodplain rather than a sandplain.

Currambene Lowlands Forest (DSF p85)

Currambene Lowlands Forest (Fig. 11) within the reserves is a relatively tall dry eucalypt forest dominated by *Corymbia maculata* with *Eucalyptus globoidea* and *E. longifolia,* occasionally with *E. paniculata, E. pilularis, E. punctata, Angophora floribunda* or *Syncarpia glomulifera.* Scattered trees of *Acacia irrorata* and *Allocasuarina littoralis* make up the subcanopy. An open shrub stratum comprises *Daviesia ulicifolia, Leucopogon juniperinus, Persoonia linearis* and *Pittosporum undulatum,* in addition to juveniles of the canopy species. Vines and twiners festoon shrubs or scramble on the ground, but rarely ascend trees. They include *Billardiera scandens, Eustrephus latifolius, Glycine clandestina, Hardenbergia violacea, Parsonsia straminea* and *Hibbertia scandens.* An open groundcover is scattered amongst a semi-continuous layer of eucalypt leaf litter and occasional patches of bare ground. It comprises graminoids, *Entolasia stricta, Echinopogon caespitosus, E. ovata, Imperata cylindrica, Lomadra filiformis, L. longifolia, L. multiflora, Poa labillardieri* and *Themeda australis* and a range of forbs including *Brunoniella pumilio, Dianella caerulea, D. revoluta, Dichondra repens, Lagenifera stipitata, Opercularia* *aspera, Tricoryne elatior* and *Vernonia cinerea.*

Currambene Lowlands Forest (DSF p85) occurs on hilly terrain with well-drained yellow loams derived from a mixture of siltstone, mudstone and sandstone. The main occurrence is in state forest to the south of Saltwater Swamp. It also occurs on a low rise that separates Saltwater Swamp from Brundee Swamp, where it has been fragmented by rural development, although a small patch occurs within the margin of Brundee Swamp NR. The community occurs extensively in the Nowra – Jervis Bay area (Tindall et al. 2004).

Illawarra Gully Wet Forest (WSF p99)

A moderate east-facing slope on the western edge of the northern section of Brundee Swamp NR supports a eucalypt forest dominated by *Corymbia maculata* with *Eucalyptus paniculata* and *E. globoidea* (Fig. 12). The understorey includes a number of mesophyllous shrub species and a more prominent groundcover of grasses and forbs. The most abundant shrubs include *Bursaria spinosa* and *Notelaea longifolia,* with *Clerodendrum tomentosum* and *Olearia viscidulum.* Vines of *Eustrephus latifolius, Tylophora barabata* and *Pandorea pandorana* are prominent amongst the shrubs, while the groundcover is dominated by *Oplismenus imbecillus, Microlaena stipoides, Commelina cyanea* and *Dichondra repens.*

This forest has a canopy composition similar to stands of Currambene Lowland Forest in the area. However, its understorey, with an abundance of mesophyllous shrubs and vines, and its prominent groundcover dominated by soft-leaved grasses, distinguishes it from that community, which typically has a sparse sclerophyllous shrub stratum and an open groundcover of wiry graminoids and forbs. The understorey features of the Brundee stand more closely resemble those of two other communities described for the south coast (Tindall et al. 2004). The mesophyllous shrubs and vines and soft-leaved grasses are characteristic of Illawarra Gully Wet Forest (WSF p99), while *Bursaria spinosa* and abundant grasses are characteristic of South Coast Grassy Woodland (GW p34). Although the forest on the western edge of Brundee Swamp NR has characteristics of all three of these communities, its species composition has closest overall resemblance to Illawarra Gully Wet Forest (WSF p99), which is mapped on several similar sheltered slopes in the vicinity by Tindall et al. (2004).

Figure 6. Regenerating stand of Estuarine Fringe Forest at Brun09 (Brundee Swamp NR) showing young *Casuarina glauca* (background), tussocks of *Juncus kraussi* subsp. *australasicus*, amidst dense growth of *Aster subulatus*, which overtops scattered native forbs.

Other vegetation

Some small, permanently inundated areas adjacent to Crookhaven River on the northern edge of Saltwater Swamp NR support dense stands of *Phragmites australis* that could not be sampled in this survey and were too small to map. These small patches represent an example of reedlands that may previously have been more extensive on the lower Shoalhaven floodplain. Along the northern boundary of Saltwater Creek NR, there are also scattered individuals of *Avicennia marina*, which occurs in larger stands below the floodgates downstream on Crookhaven River.

Vegetation structure and fuel characteristics

Coastal Sand Swamp Forest was the most structurally complex vegetation in the study area, with four vertical strata, each with a relatively high cover of foliage (Table 3). Estuarine Saltmarsh had the simplest structure, generally with only one or

Figure 7. Estuarine Creekflat Scrub at Brun01 (Brundee Swamp NR) showing *Melaleuca ericifolia* in the canopy and as smaller shrubs along a drainage line beneath a gap in the canopy.

Figure 8. Estuarine Saltmarsh at site Salt05 (in Saltwater Swamp NR) showing tussocks of *Juncus kraussi* subsp. *australasicus* with a mat of *Selliera radicans* and occasional *Sarcocornia quinquefaria*.

Figure 9. Sand Swamp Sclerophyll Forest at site Salt11 (Saltwater Swamp NR) showing a mixed tree layer of *Eucalyptus robusta* (background right), *Melaleuca* spp. and *Casuarina glauca* (centre) with a structurally complex groundcover of *Hypolepis muelleri*, numerous grasses and forbs.

two strata, although it consistently had the greatest groundcover. Vegetation of the floodplain had shorter trees than the eucalypt forests of the surrounding hills. The basal area of trees on the floodplain and the hills was generally similar (Table 3); however, the floodplain tended to have greater densities of smaller trees (Casuarina and Melaleuca spp.), while the hills had fewer larger trees (Eucalyptus and Corymbia). There was a clear inverse relationship between the cover of tree canopies and groundcover where Casuarina glauca was one of the dominant tree species (Fig. 13). However, there was no clear relationship where Melaleuca or Eucalyptus trees were dominant.

Litter fuels were generally greater than elevated scrub fuels throughout the reserves (Table 4). Floodplain Swamp Forest and Currambene Lowland Forest generally supported the highest levels of bushfire fuels, due to leaf litter contributions from *Casuarina glauca* and *Eucalyptus* or *Corymbia* spp., respectively. Currambene Lowland Forest accounts for a relatively small portion of the reserves (Table 1). The majority of vegetation on the floodplain supports low to moderate fuel levels. For most of the Floodplain Swamp Forest and Estuarine Fringe Forest, litter fuels were composed primarily of densely stacked *Casuarina* branchlets, which were poorly aerated and therefore unlikely to support a rapid rate of fire spread. The flammability of these and other floodplain plant communities is also likely to be reduced by the concentration of mineral salts in foliage, which is likely to be higher than that in eucalypt-dominated vegetation of the surrounding hills.

Flora

One hundred and forty-nine native plant species were recorded in the 24 quadrats located within the two reserves (Appendix 1). The majority of native plant species occurred in the eucalypt forest communities around the margins of the floodplain, while the floodplain vegetation was comparatively species-poor (Table 5). Poaceae was the most prominent plant family on both the floodplain and the surrounding hills, with 25 species represented in total. Cyperaceae (12 species), Asteraceae (5 species), Myrtaceae (5 species), Juncaceae (3 species) and Chenopodiaceae (3 species) were also represented by numerous species on the floodplain. The plant families, in addition to Poaceae, that were represented by numerous species on the hills included Fabaceae (12 species), Myrtaceae (9 species), Asteraceae (4 species) and Lomandraceae

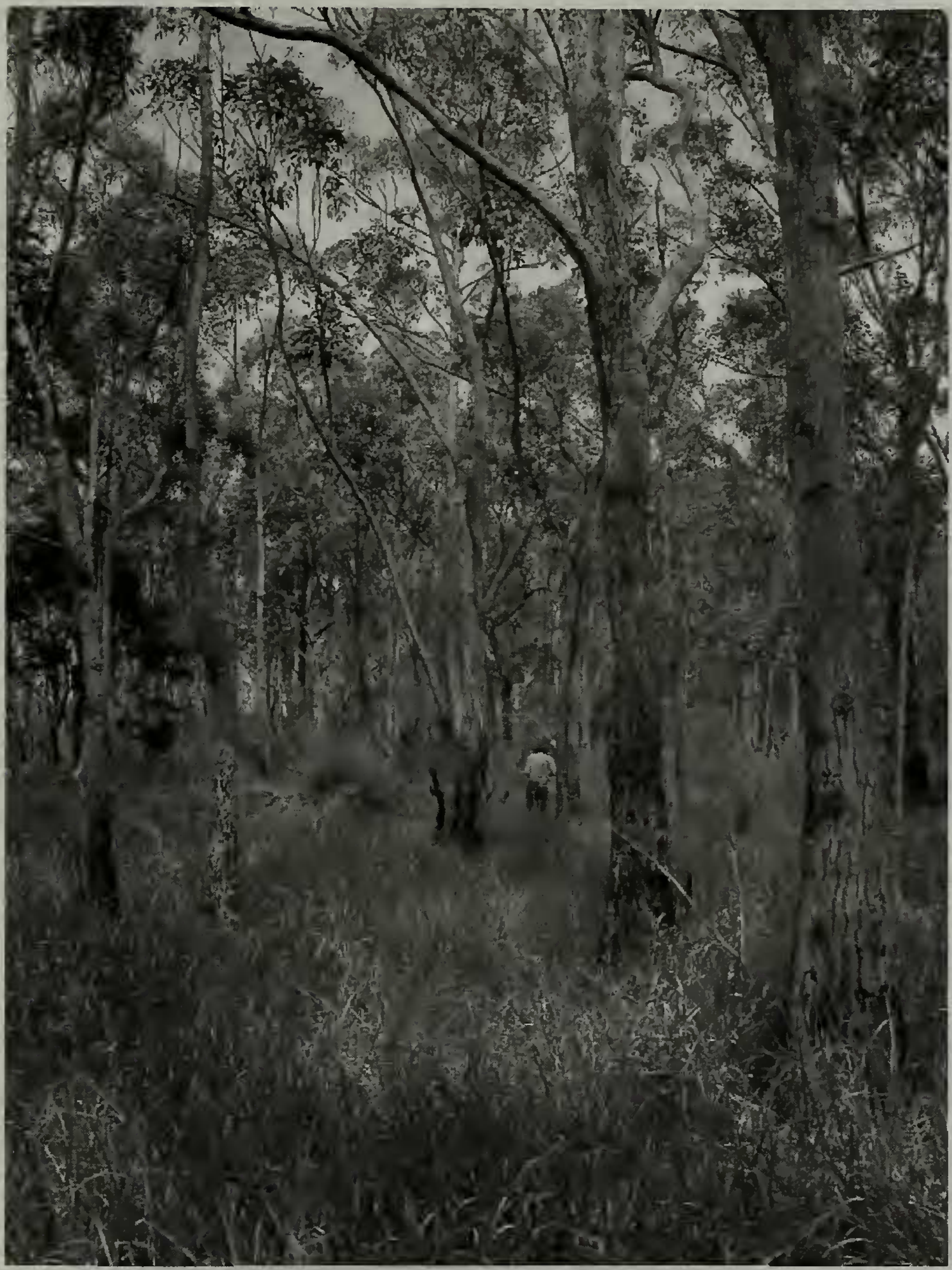

Figure 10. Coastal Sand Swamp Forest at site Brun06 (Brundee Swamp NR) showing *Eucalyptus robusta* with a sparse shrub stratum and continuous ground layer dominated by *Imperata cylindrica* and diverse herb layer. It is likely that the structural complexity of this stand has been reduced (cf. site Salt11, Fig. 8) as a result of past grazing and burning, although a substantial plant diversity is retained in the ground layer.

(3 species).

Thirty-six exotic plant species were recorded within the reserves (Appendix 1). The most frequently recorded of these were *Cirsium vulgare, Aster subulatus, Chenopodium album, Phytolacca octandra* and *Sonchus oleraceus*. The majority of exotic species recorded were short-lived disturbance opportunists or introduced pasture grasses with agricultural origins, reflecting recent land use in the reserves and continuing land use in the surrounding area. Many of these species are unlikely to persist in high abundance in the absence of continuing disturbance, such as livestock grazing; however, a number of exotic species are potentially aggressive weeds capable of further spread, excluding native species and reducing the diversity of native vegetation. The most problematic weed species recorded include *Aster subulatus, Lantana camara, Pennisetum clandestinum, Senecio madagascariensis* and *Xanthium occidentale*. *Aster, Senecio* and *Xanthium* are relatively abundant throughout the treeless area in the northern two-thirds of Brundee Swamp NR, while *Lantana* and *Pennisetum* appear to be largely restricted to the area mapped as Illawarra Wet Gully Forest on the western edge of the reserve. With the exception of *Aster*, these species are either declared noxious weeds or listed as a Key Threatening Process under the Threatened Species Conservation Act.

Vegetation and landscape history

The earliest description of vegetation on the Shoalhaven River floodplain is from the journal account of Lieutenant B. Kent and James Meehan, who explored the area in February 1805. Weatherburn (1960) reconstructed and mapped the route of their exploration, annotating a map with their observations about a number of locations. Kent and Meehan apparently did not inspect Brundee and Saltwater Swamps directly, but made observations from very close-by. The following observation was made from the southern bank of the Shoalhaven River,

> "This place is an extensive plain with no trees on, is very low and apparently swampy, is very thick grass intermixed with reeds. The soil is a deep black mould."

Weatherburn (1960) interprets the location of this observation as close to Numbaa, opposite where Broughton Creek joins the Shoalhaven River, about

Figure 11. Currambene Lowlands Forest at site Salt15 (in Saltwater Swamp NR) showing the dominant tree *Corymbia maculata*, with *Eucalyptus globoidea*, a sparse shrub stratum and an open understorey of grasses, graminoids and forbs amongst copious leaf litter.

Figure 12. Illawarra Gully Wet Forest at Brun07 (Brundee Swamp NR) dominated by *Corymbia maculata* with an open shrub layer and prominent ground layer of forbs and soft-leaved grasses, including *Microlaena* and Oplismenus. A clump of *Lantana camara* dominates the middleground.

3 km north of the northern edge of Brundee Swamp. Terrara Swamp is very close to this location and could have supported very similar vegetation to Brundee Swamp at that time. Kent and Meehan made similar observations about thick grass and reeds from Broughton Creek near Jaspers Brush.

On the Crookhaven River, at a location interpreted by Weatherburn (1960) as about 1 km downstream from Saltwater Swamp, Kent and Meehan make the following observation,

> "This bank is low part of the brush, apparently good soil."

Looking further upstream, they remark,

> "I suppose there is a good quantity of good ground on the banks of this river."

Property boundaries were surveyed in the area during the period 1840-1885 and 1905 for the purpose of drawing portion plans of land assigned to settlers (Fig. 14). The surveyors frequently identified trees to mark the ends of their survey lines and occasionally recorded remarks about the land, vegetation and soils on the plan. A parcel of land that separates Brundee Swamp NR from Saltwater Creek NR (Parcel 1 on Fig. 14) was surveyed in 1842 and was described as follows,

> "Swamp and poor forest land timbered with swamp oak and spotted gum."

One corner point of this parcel surveyed on the northern boundary of Saltwater Creek NR was marked on a tree identified as "Honeysuckle" [likely to be *Banksia integrifolia*] and another on the eastern boundary of Brundee Swamp on a tree identified as "Apple" [likely to be *Angophora floribunda* or *A. subvelutina*]. Immediately to the north of this block, a land parcel surveyed in 1885 (Parcel 2 on Fig. 14), notes the occurrence of "Oak" [*Casuarina glauca*] and "Mangrove" [*Avicennia marina*] on a tributary creek that emerges from the eastern edge of Brundee Swamp. The survey plan for this portion carries the annotation,

> "Some swamp was cleared."

Another block on the south-western boundary of Brundee Swamp NR (Parcel 3 on Fig. 14), surveyed in 1856 was described as,

> "Rich swamp, fresh and brackish."

None of the other portion plans in the vicinity are annotated with descriptions. However, a number of them identify "Oak" as a marker tree, particularly in locations on the margins of the floodplain or adjacent to streamlines. Many of the properties adjoining Brundee Swamp NR that were surveyed in 1908 identify their markers as "stakes" or "posts", suggesting either a lack of suitable trees or a change in survey practice that preferred to install markers, rather than use existing trees.

Two copies of the Numbaa Parish map obtained from the NSW Land and Property Information Centre (Fig. 15) show the general extent of "swamp" in the area, but carry no other description of the vegetation. The area immediately north of Brundee Swamp is annotated "subject to tidal inundation," and the small tributary of the Crookhaven River emerging from the eastern boundary of the present nature reserve is marked "tidal".

Table 3. Structural characteristics of the vegetation. Data are means with standard errors.

Stratum:	Tree			Shrub		Reed/rush		Grass/forb		Litter
Community	Basal area ($m^2.ha^{-1}$)	Max. Height (m)	Cover (%)	Max. Height (m)	Cover (%)	Max. Height (m)	Cover (%)	Max. Height (m)	Cover (%)	Cover (%)
Floodplain Swamp Forest (FOW p105)	20(3)	11(0)	39(3)	6(-)	3(3)	3(1.8)	29(11)	0.4(0.1)	11(4)	92(5)
Estuarine Fringe Forest (FOW p106)	28(12)	10(2)	39(10)	2.5(-)	2(2)	2(0.8)	19(6)	0.2(0)	19(8)	65(19)
Estuarine Creekflat Scrub (FOW p107)	14(14)	7(3)	55(15)	-(-)	0(-)	-(0.9)	2(0)	0.1(0)	5(4)	85(5)
Estuarine Saltmarsh (SL p509)	1(0)	7(1)	2(1)	-(-)	0(-)	-(1.2)	52(19)	0.2(0)	53(20)	1(1)
Coastal Sand Swamp Forest (FOW p45)	22(3)	17(4)	48(14)	1.9(0.1)	2(1)	1(2)	23(15)	0.5(0.1)	60(23)	18(3)
Currambene Lowland Forest (DSF p85)	37(1)	22(2)	38(3)	3(0.7)	2(1)	1(0)	0(-)	0.6(0.1)	14(3)	93(3)
Illawarra Gully Wet Forest (WSF p99)	26(-)	32(-)	50(-)	5(-)	15(-)	-(-)	0(-)	0.4(-)	90(-)	10(-)

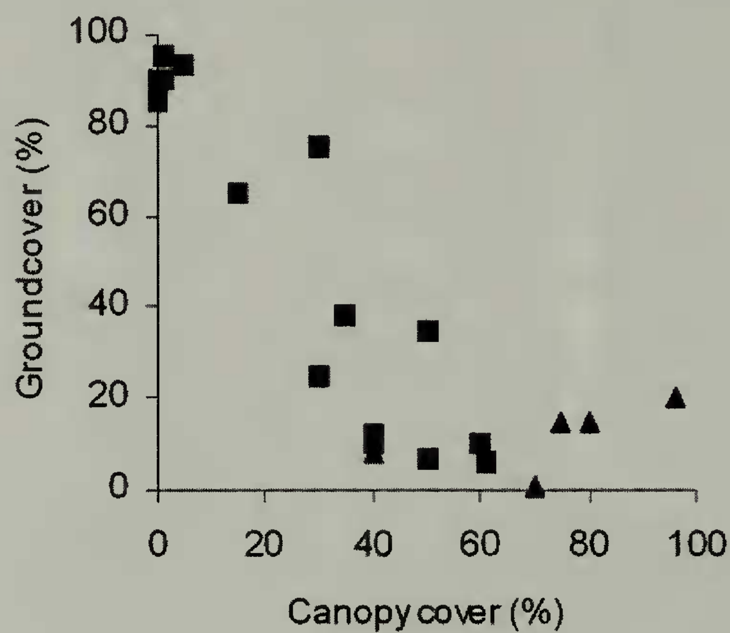

Figure 13. Relationship between tree canopy cover and groundcover on the floodplain. Squares - sites with canopy dominated by *Casuarina*. Triangles - sites with canopy dominated by *Melaleuca*.

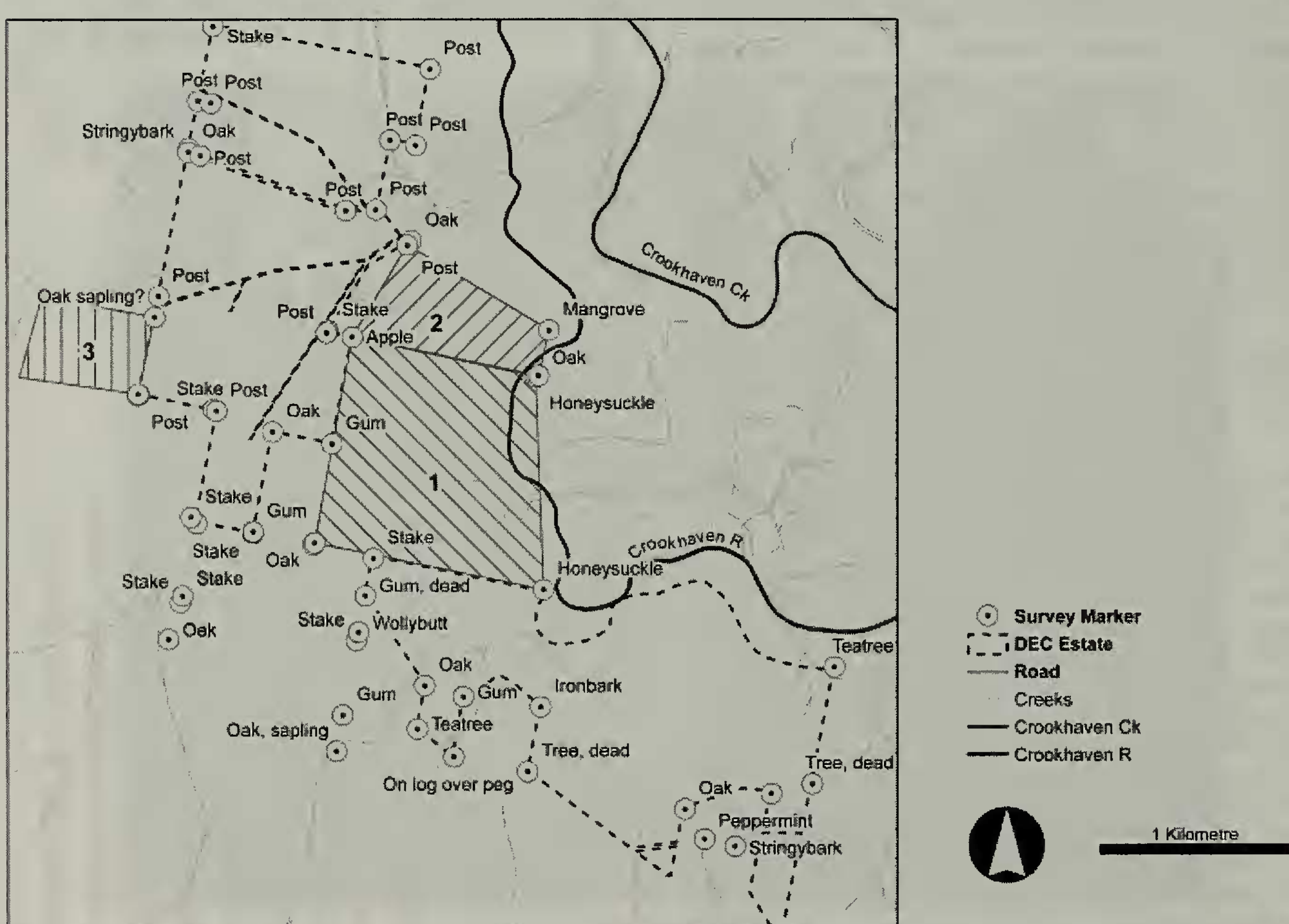

Figure 14. Location of portion plan survey points showing identity of trees used as survey markers 1842 - 1905. Surveyors' descriptions of land parcels 1, 2 and 3 are given in the Results text.

Table 4. Estimated bushfire fuel loads. Means and standard errors in parentheses in tonnes per hectare.

Community	Ground fuel	Elevated scrub fuel	Total fine fuel
Floodplain Swamp Forest (FOW p105)	25 (5)	4 (2)	29 (4)
Estuarine Fringe Forest (FOW p106)	10 (3)	4 (2)	14 (4)
Estuarine Creekflat Scrub (FOW p107)	12 (7)	5 (2)	17 (5)
Estuarine Saltmarsh (SL p509)	0 (0)	5 (2)	5 (2)
Coastal Sand Swamp Forest (FOW p45)	3 (2)	6 (2)	9 (1)
Currambene Lowland Forest (DSF p85)	22 (6)	1 (0)	23 (6)
Illawarra Gully Wet Forest (WSF p99)	2 (-)	2 (-)	4 (-)

Table 5. Mean (standard errors in parentheses) species richness and relative abundance of exotic species in six plant communities of Brundee Swamp NR and Saltwater Swamp NR. (C/A – Braun-Blanquet Cover-Abundance).

Community	Native species richness	Exotic species richness	Exotic species as proportion of the total	Sum of C/A scores for exotic species
Floodplain Swamp Forest (FOW p105)	13.7 (2.5)	0.8 (0.7)	5.7 (3.0)%	1.3 (0.8)
Estuarine Fringe Forest (FOW p106)	7.4 (0.5)	2.0 (0.8)	21.3 (5.8)%	4.6 (2.2)
Estuarine Creekflat Scrub (FOW p107)	13.3 (4.3)	3.7 (1.2)	21.6 (5.5)%	.6.3 (1.6)
Estuarine Saltmarsh (SL p509)	9.0 (0.7)	6.0 (0)	40.0 (1.8)%	12.3 (0.6)
Coastal Sand Swamp Forest (FOW p45)	28.8 (1.7)	3.3 (0.5)	10.2 (1.1)%	3.3 (0.5)
Currambene Lowland Forest (DSF p85)	41.7 (3.9)	0.7 (0.5)	1.6 (0.1)%	0.7 (0.5)
Illawarra Gully Wet Forest (WSF p99)	49 (-)	15 (-)	23.4 (-)%	27 (-)

The Parish map shows the location of tracks and streamlines, but does not show the location of any artificial drains. One copy of the map carries later annotations than the other. The latest date on one copy of the map is 7th July 1903 (Fig. 15a), while the other copy carries the date 13th November 1903. This second map (Fig. 15b) shows Brundee Swamp divided into two or more portions, each of which is annotated with an estimate of the area in acres "ex drains". There are also annotations at the base of this map referring to monetary assistance for drainage work about Brundee Swamp, the formation of a Union under the Drainage Act, and a warning to settlers "re rate liabilities in Drainage Trust Districts". Portion plans from the floodplain of Broughton Creek (a northern tributary of the lower Shoalhaven River), approximately 8 km north of Brundee Swamp, show drains in existence there during 1896.

Figure 15. Two copies of the Numbaa Parish map showing (a - upper) Brundee Swamp, which carries no reference to drains and (b - lower) Saltwater Swamp and the southern part of Brundee Swamp, marked with later annotations referring to drains and drainage works. Obtained from NSW Department of Lands website (http://www.lands.nsw.gov.au/survey_mapping/parish_maps)

A new phase of drain construction was initiated in the area after the New South Wales Grant (Flood Mitigation) Act (1964) was introduced (Dalmazzo et al. 2000). The new drains were generally deeper and more effective than the older drains. In addition, floodgates were built on the Crookhaven River to prevent tidal inundation of the swamps, and the river was dredged to increase drainage and diverted at Springbank Road via a new drain to Crookhaven Creek. This significantly reduced the volume of water flowing through Saltwater Swamp (Dalmazzo et al. 2000).

Recent aerial photography shows the change in distribution of woody vegetation for an area of Brundee Swamp NR over the period 1996-2002 (Figure 16). Over that period, forest, woodland or scrub have replaced treeless vegetation on some areas of the floodplain. The most striking change has occurred on a slightly elevated area along the eastern edge of Brundee Swamp NR, where there has been a substantial increase in the density of small trees, mainly *Casuarina glauca*. Scattered shrubs, mainly *Melaleuca ericifolia*, also appear to have become more prominent on some lower lying parts of the floodplain in the central part of the reserve.

Quadrat samples and field reconnaissance in the regenerating area of Estuarine Fringe Forest in Brundee Swamp (mapped as FOW p106a, Fig. 2) during February 2006 also suggested that substantial recruitment of *Casuarina glauca* and, to a lesser extent *Melaleuca ericifolia,* had occurred in recent years.

DISCUSSION

Vegetation Patterns

The vegetation of Brundee and Saltwater Swamps is a mosaic of herbfields, scrubs and woodlands. The distribution of these vegetation types is determined to a large extent by the frequency, depth and duration of inundation, the height of the water table and the level of salinity in the water. Both of the reserves include small areas of eucalypt forest on elevated lithic substrates that adjoin the floodplain.

The influences of hydrology and salinity on native vegetation of the floodplain may be inferred from the distribution of plant communities within the reserves and the surrounding landscapes. Eucalypt forests (Currambene Lowland and Illawarra Gully Wet Forest) are essentially excluded from floodplain landscapes in this area. They are extensive on the freely-draining, hilly terrain on lithic substrates that surround the floodplains, but are restricted to small marginal portions of the two nature reserves. Coastal Sand Swamp Forest is restricted to a narrow zone where the toeslopes of hills adjoin the floodplain. Here, the soils have a somewhat sandy texture and periodic inundation is by predominantly fresh water, which accumulates in depressions around the margins of the floodplain after it descends from the surrounding hills. The mixed canopy composition of Eucalyptus, Melaleuca and Casuarina reflects the transitional character of this habitat.

Estuarine Creekflat Scrub is associated with well-developed humic soils on broad flats of the floodplain. These habitats appear to receive greater quantities of flowing water, which may be slightly more saline than in habitats that support Coastal Sand Swamp Forest. Floodplain Swamp Forest, Estuarine Fringe Forest and Estuarine Saltmarsh form a replacement sequence of communities with decreasing elevation and increasing soil salinity on the open floodplain. Subtle variations in relief of the floodplain appear to influence the distributions of these three communities, although their ecological relationships are likely to have been obscured by disturbances to vegetation and soils, and by alteration to drainage patterns. Nevertheless, Floodplain Swamp Forest is apparently associated with raised levees along streams and subtle rises around the margins of the floodplain, whereas Estuarine Saltmarsh is confined to low-lying sites exposed to occasional (or past) tidal inundation.

Vegetation Change

There is little doubt that substantial changes have occurred to floodplain vegetation since settlement as a consequence of clearing, grazing and changes to drainage and tidal flows. However, the precise causes and mechanisms of change in the Brundee-Saltwater area are not well understood, nor is the distribution and make-up of native vegetation prior to agricultural development of the floodplain. It seems likely that these changes occurred in a series of episodes as particular events took place, including initial clearing, introduction of livestock, construction of drainage channels, construction of deeper drains, installation of tidal gates and successive changes to stocking rates.

The pre-settlement vegetation of the floodplain apparently included extensive treeless areas with thick grass intermixed with reeds. This vegetation now appears to be locally extinct, as no native grasslands were observed in or around the study area. Based on remnants observed on other floodplains (Keith 2004), Paspalum distichum (water couch) was a likely dominant grass species. The community is also likely to have included a number of other grass genera, as well as sedges (notably Eleochaeris, Cyperus and Schoenus) and forbs from families such as Ranunculaceae, Apiaceae and Menyanthaceae. The most abundant reed species are likely to have been Phragmites australis, which persists in the vicinity today in small patches and drainage lines inundated by brackish water, or possibly Juncus kraussii. The latter species is abundant in contemporary treeless areas that are inundated with brackish water, but less frequently than sites supporting P. australis. Other possible 'reeds' include other species of Juncus, Baumea and other cyperaceous genera. Early accounts do not specifically mention saltmarsh, although it seems likely to have been part of the pre-European landscape, particularly as tides reached as far upstream as the northern part of Brundee Swamp.

Woody vegetation was also part of the pre-settlement floodplain landscape, although its distribution was apparently patchy. The available historical records and current ecological relationships suggest that woodlands and forests were mainly confined to the banks of streams and drainage lines and to slightly elevated areas, including levees and gentle slopes around margins of the floodplain. Casuarina and Melaleuca are likely to have been the major genera of trees, although historical descriptions record honeysuckle (Banksia) and brush (rainforest genera such as Acmena) along the banks of floodplain streams.

After European settlers brought cattle onto the floodplain, exotic pastures replaced the grasslands, and most of the woodlands and forests. The surveys and land grants dating from 1842 marked an intensification of earlier grazing activities by squatters. The use of stakes or posts, rather than marker trees, in the 1905 surveys may lend tacit support to the suggestion that little native woody vegetation remained on the floodplain at that time. However, this could also be explained by a change in survey practice, and the fact that some survey points were located in areas that were originally treeless. While some of these survey points are located in areas that now support forests of Eucalyptus or Casuarina, few of the contemporary trees are large enough to suggest pre-settlement origin.

Co-ordinated drainage work to make the area more suitable for agriculture probably began in the Brundee-Saltwater area in the early twentieth century (possibly 1903), although drains were in existence elsewhere on the Shoalhaven a decade earlier. Drains modified the hydrology of the floodplain by lowering the water table and reducing the duration of inundation. If appreciable areas of native grasslands and reedlands persisted into the twentieth century, the construction of drains would have accelerated their replacement by exotic pasture.

Drainage works also had a profound effect on soil and water chemistry, particularly after deep drains and tidal gates were constructed in the second half of the twentieth century. Widespread oxidation of organic floodplain soils resulted in the release of acid sulphates and discharge of strongly acidic water into local streams, as was found behind the floodgates on the Crookhaven River at Culburra Road during 1991-92 (Lawrie 2005). The level of stored acidity appears to be moderate in well-vegetated parts of the natures reserves in comparison to other parts of the floodplain (Lawrie 2005).

The reduced incursion of saline water after installation of tidal gates on the Crookhaven River is expected to have reduced the area of saltmarsh and mangrove vegetation in and around Brundee and Saltwater Swamps. Nevertheless, the persistence of salt-tolerant plant species, including native species, *Juncus krausii*, *Casuarina glauca*, *Leptinella longipes*, *Lobelia anceps*, *Sarcocornia quinqueflora* subsp. *quinqueflora* and *Selliera radicans*, as well as exotics, *Aster subulatus* and *Chenopodium album*, in both Brundee and Saltwater Swamps suggests that an appreciable saline influence still exists in the reserves. Recent analysis of a soil profile in Saltwater Swamp NR confirmed this inference (Lawrie 2005). The sample was taken from the floodplain, approximately 150m north of site Salt15 (Fig. 2). The soil profile was found to be moderately to strongly saline, with salinity increasing with depth from c. 900 mg chloride per kg dry soil near the soil surface to over 3000 $mg.kg^{-1}$ below 1 m depth. Surface soil was too saline for most pasture plants and no roots were found below 55cm, probably due to the increased salinity at this depth (Lawrie 2005). This salinity may be partly residual, although some tidal incursion may occur, for example, when large tides and floods breach the tidal barriers.

The role of fire in vegetation dynamics on the floodplain is uncertain. There was evidence of charring on stems of some trees, suggesting that parts of the reserves had burnt some time in the past 10-20 years. We observed no evidence of recent subterranean (peat) fires during field reconnaissance. Such fires may have a substantial impact on woody vegetation in the wetlands. Typically, peat fires spread slowly and are difficult to distinguish. Under most fire conditions, however, the majority of the reserve area is not expected to be highly flammable due to the poorly aerated and/or low volume ground fuels and high salts content of live and dead foliage.

The most recent episode of vegetation change apparently involves the encroachment of woodland and forest into treeless areas of the floodplain, through the recruitment of *Casuarina glauca* and *Melaleuca ericifolia*. The most likely cause of these changes is the recent removal of livestock from parts of the floodplain within the reserves. Evidence supporting this interpretation includes the following:

- The encroachment of trees and shrubs since 1996 coincides with a synchronous reduction and removal of livestock associated with public acquisition of the grazing leases prior to dedication of the reserves in January 2001;
- No significant drainage or tidal works have occurred since 1996;
- The recent drought largely post-dates the beginning of woody thickening as shown on the aerial photographs flown in 2002 (Fig. 16); and
- There has been little if any expansion of woody vegetation outside the reserves where stocking rates have remained at similar levels.

The abundance of some weed species on the floodplain, notably *Aster subulatus*, may also be a recent response to the change in grazing regime. However, the inverse relationship between tree canopy cover and ground cover (Fig. 14) suggests that the abundance of both native and exotic groundcover plant species will decline as the densities of shrubs and small trees increase further and cast more shade at ground level.

It is uncertain whether the expansion of forested wetland vegetation into abandoned pastures represents a recent return to pre-settlement vegetation. Anecdotal information suggests that some areas of the floodplain had been treeless prior to settlement (Weatherburn 1960), although location-specific information for Brundee and Saltwater Swamps is extremely limited. The nature of longer term historical changes depends on the largely unknown effects that construction of drainage channels had on native vegetation. It seems likely that regrowth vegetation will differ from the original vegetation because of lowered water tables,

Figure 16. Aerial photographs of Brundee Swamp flown in (a - upper) 1996 and (b - lower) 2002.

shorter periods of inundation and reduced salinity. For example, soil drying and oxidation could have made sites that previously supported open wetlands more suitable for colonisation by native woody species, which has been kept in check until recently released from grazing. However, inferences about the nature and causes of historical vegetation change remain speculative in the absence of appropriate data.

Conservation of Floodplain Vegetation

Irrespective of the changes that may have taken place in the past, Brundee and Saltwater Swamp Nature Reserves both contain important examples of Endangered Ecological Communities (EEC) that once covered extensive areas on coastal floodplains of New South Wales before these areas were developed for agriculture. The endangered floodplain communities make up the majority of the two reserves.

Floodplain Swamp Forest, Estuarine Fringe Forest and Estuarine Creekflat Scrub represent three variants of the Swamp Oak Floodplain Forest EEC. None of these variants has appreciable representation in conservation reserves in New South Wales. The first two of these map units have less than 3% of their estimated pre-settlement distribution within reserves in southern NSW (Tozer et al. 2006), of which Brundee and Saltwater Swamp Nature Reserves make up the major portion. While estuaries and coastal lakes to the south of Shoalhaven River retain many small stands of Estuarine Creekflat Scrub, its occurrences further north are generally small degraded remnants of the original distribution. The reserves on the Shoalhaven floodplain are therefore important for the conservation of all three components of the Swamp Oak Floodplain Forest EEC.

Coastal Sand Swamp Forest, part of the Swamp Sclerophyll Forest on Floodplains EEC, is a naturally restricted community on the south coast, of which almost half has been cleared in the past. Its main representation in conservation reserves is on the sandy soils in Jervis Bay National Park. Although small, the stands in Brundee and Saltwater Swamp Nature Reserves are important because they are associated with a major floodplain unlike those associated with the Jervis Bay sandplain to the south. Furthermore, they make important contributions to biodiversity, harbouring a distinctive combination of plant species and providing a structurally complex habitat that is not replicated by other vegetation types in the area. Larger areas of Coastal Sand Swamp Forest exist on private property adjacent to, and nearby the boundaries of both reserves. The condition of these is unknown, but warrants investigation with a view to fostering sympathetic management of the community in the area.

Stands of Estuarine Saltmarsh within the reserves represent a small part of the floristic and distributional ranges of the highly variable Coastal Saltmarsh EEC, which extends in small patches throughout the coastline of New South Wales. In many parts of this range, there are signs of mangrove transgression, which potentially threatens the persistence and diversity of saltmarsh vegetation (Saintilan and Williams 1999). There is currently no evidence of such changes in Brundee and Saltwater Swamp Nature Reserves, perhaps because saltmarsh there represents the terrestrial extreme of the variation in the community and because minimal tidal influence is maintained by current tidal regulation. Nevertheless, the status of saltmarsh within the reserves is uncertain and the possibility of encroachment by *Casuarina glauca* or *Melaleuca ericifolia* warrants continued monitoring.

Past and ongoing changes in native vegetation demonstrate the sensitivity of floodplain vegetation to environmental change. In such disequilibrium systems, an important goal for contemporary management of the reserves is conservation of a dynamic mosaic of the endangered ecological communities that are under threat throughout the broader region. The sensitivity of the floodplain biota to environmental change also demands an adaptive approach to management, whereby actions are responsive to the direction and magnitude of changes in the system (Burgman and Lindenmeyer 1998). Adaptive strategies of this kind rely on monitoring to diagnose contemporary responses and inform decisions about future actions.

The permanently marked floristic sample sites established in this study provide a crude contemporary baseline for assessing changes in composition and structure of the vegetation in the future. However, it is likely that the sampling design will require modification to provide answers to specific management questions. To understand the role of grazing in future vegetation changes on the floodplain, for example, it would be necessary to sample a number of sites where livestock continue to graze, perhaps under a range of regimes (stocking rates, frequency and duration of spelling, etc.). This would require co-operation with neighbouring landholders.

The sampling design could also be adapted to examine the effects of any future changes in drainage and tidal management regimes, through the establishment of additional samples in suitable control subcatchments. For example, the installation of two-way floodgates has been suggested as a means of increasing water quality by regular tidal flushing (Lawrie 2005). A potential consequence of such a change is the replacement of swamp oak forest with saltmarsh in the low lying areas. Sustainable conservation of biodiversity on coastal floodplains depends on continuing evaluation of vegetation responses to such changes in water management, and on improved understanding of mechanisms that influence vegetation dynamics in these landscapes.

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Appendix. List of vascular plant species recorded for Brundee Swamp NR and Saltwater Swamp NR. Site NOW005A was outside the reserves. Values are Braun-Blanquet cover-abundance scores (see Methods). * denotes introduced species.

Community	p107	p105	p509	p85	p107	p45	p34	p106	p106	p105	p45	p106	p107	p105	p509	p105	p105	p509	p105	p106	p106	p45	p85	p45	p85
Site	Brun 01	Brun 02	Brun 03	Brun 04	Brun 05	Brun 06	Brun 07	Brun 08	Brun 09	NOW 004A	NOW 005A	NOW 010A	NOW 011A	Salt 01	Salt 02	Salt 03	Salt 04	Salt 05	Salt 06	Salt 07	Salt 08	Salt 09	Salt 10	Salt 11	Salt 15
Acacia binervata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Acacia irrorata subsp. *irrorata*	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Acacia longifolia	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Acacia mearnsii	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Adiantum aethiopicum	-	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	3	-	1	-
**Ageratina adenophora*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Allocasuarina littoralis	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1
Alternanthera denticulata	-	2	-	-	-	-	1	1	1	-	-	-	1	-	-	1	-	-	1	2	-	-	-	-	-
**Anagallis arvensis*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
**Andropogon virginicus*	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Angophora floribunda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
**Araujia sericifera*	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aristida vagans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Arthropodium minus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Arthropodium species B	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
**Aster subulatus*	-	-	5	-	4	-	-	-	5	-	-	3	-	-	2	-	-	2	-	-	1	-	-	-	-
Austrodanthonia racemosa var. *racemosa*	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baumea articulata	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
**Bidens pilosa*	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Billardiera scandens	-	1	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
Boronia polygalifolia	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
**Bromus catharticus*	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brunoniella pumilio	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2

Community	p107	p105	p509	p85	p107	p45	p34	p106	p106	p105	p45	p106	p107	p105	p509	p105	p105	p509	p105	p106	p106	p45	p85	p45	p85
Site	Brun 01	Brun 02	Brun 03	Brun 04	Brun 05	Brun 06	Brun 07	Brun 08	Brun 09	NOW 004A	NOW 005A	NOW 010A	NOW 011A	Salt 01	Salt 02	Salt 03	Salt 04	Salt 05	Salt 06	Salt 07	Salt 08	Salt 09	Salt 10	Salt 11	Salt 15
Bursaria spinosa	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calochlaena dubia	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex appressa	1	-	-	-	-	-	-	-	-	-	-	-	4	-	-	1	-	-	-	-	-	-	-	-	-
Carex breviculmis	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex gaudichaudiana	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex inversa	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Carex longebrachiata	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Cassytha pubescens	-	-	-	-	-	2	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-	1	-	-	-
Casuarina glauca	1	5	2	-	1	-	-	6	4	6	-	1	1	5	1	5	4	2	6	5	6	2	-	4	-
Centella asiatica	2	2	-	3	-	2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	3	-
**Centaurium erythraea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-
**Chenopodium album*	-	-	3	-	3	-	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
**Cinnamomum camphora*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
**Cirsium vulgare*	2	1	-	1	-	1	-	-	-	-	-	-	1	-	3	-	-	2	-	-	-	1	-	1	-
Clematis aristata	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clematis glycinoides var. *glycinoides*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Clerodendrum tomentosum	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Commelina cyanea	-	2	1	1	-	-	4	1	-	1	-	-	2	2	-	2	3	-	2	1	1	-	-	2	-
**Conyza bonariensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
**Conyza sumatrensis*	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
**Conyza* spp.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corymbia maculata	-	-	-	4	-	-	5	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	5	-	5
**Cotula coronopifolia*	-	-	2	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Cymbopogon refractus	-	-	-	3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cymbidium suave	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cynodon dactylon	2	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Cyperus imbecillis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-

Community	p107	p105	p509	p85	p107	p45	p34	p106	p106	p105	**p45**	p106	p107	p105	p509	p105	p105	p509	p105	p106	p106	p45	p85	p45	p85
Site	Brun 01	Brun 02	Brun 03	Brun 04	Brun 05	Brun 06	Brun 07	Brun 08	Brun 09	NOW 004A	NOW 005A	NOW 010A	NOW 011A	Salt 01	Salt 02	Salt 03	Salt 04	Salt 05	Salt 06	Salt 07	Salt 08	Salt 09	Salt 10	Salt 11	Salt 15
Cyperus lucidus	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
Cyperus polystachyos	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	3	-	2	1	-	-	-	-	-
**Dactylis glomerata*	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Daviesia ulicifolia	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Desmodium rhytidophyllum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-
Desmodium varians	-	-	-	4	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Deyeuxia quadriseta	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dianella caerulea	-	-	-	2	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3	-	1
Dianella longifolia	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dianella revoluta var. *revoluta*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Dichelachne micrantha	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dichelachne inaequiglumis	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dichondra repens	-	-	-	3	-	2	3	-	-	-	1	-	-	-	-	-	2	-	-	-	-	1	-	2	2
Digitaria parviflora	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Echinopogon caespitosus var. *caespitosus*	-	-	-	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Echinopogon ovatus	2	1	-	2	-	2	3	-	-	-	2	-	-	-	-	-	2	-	-	-	1	-	1	3	-
Einadia hastata	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Einadia trigonos	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eleocharis acuta	2	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-
Elymus scaber var. scaber	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Entolasia marginata	-	2	-	-	-	2	2	-	-	2	4	-	-	2	-	4	3	-	3	-	-	4	-	3	-
Entolasia stricta	-	-	-	3	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4	4	3
Eucalyptus botryoides	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eucalyptus globoidea	-	-	-	4	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2
Eucalyptus longifolia	-	1	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4
Eucalyptus paniculata subsp.	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2

Community	p107	p105	p509	p85	p107	p45	p34	p106	p106	p105	p45	p106	p107	p105	p509	p105	p105	p509	p105	p106	p106	p45	p85	p45	p85
Site	Brun 01	Brun 02	Brun 03	Brun 04	Brun 05	Brun 06	Brun 07	Brun 08	Brun 09	NOW 004A	NOW 005A	NOW 010A	NOW 011A	Salt 01	Salt 02	Salt 03	Salt 04	Salt 05	Salt 06	Salt 07	Salt 08	Salt 09	Salt 10	Salt 11	Salt 15
paniculata																									
Eucalyptus pilularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Eucalyptus punctata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Eucalyptus robusta	-	-	-	-	-	5	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	1	-	4	-
Eustrephus latifolius	-	-	-	2	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Gahnia clarkei	1	-	-	-	-	2	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gahnia sieberiana	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Galium propinquum	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geitonoplesium cymosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Geranium solanderi var. *solanderi*	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glycine clandestina	-	-	-	4	-	1	2	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	3	1	2
Glycine microphylla	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	3	-	-	-
Glycine tabacina	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gonocarpus tetragynus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Hardenbergia violacea	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Hibbertia empetrifolia subsp. *empetrifolia*	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hibbertia scandens	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydrocotyle peduncularis	-	-	-	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypericum gramineum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
**Hypochaeris glabra*	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-
**Hypochaeris radicata*	2	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypolepis muelleri	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	4	-
Imperata cylindrica var. *major*	-	-	-	4	-	5	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Isolepis inundata	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Joycea pallida	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus kraussii subsp. *australiensis*	-	2	7	-	-	-	-	4	5	2	-	4	-	-	4	-	-	5	3	5	4	-	-	-	-

Community	p107	p105	p509	p85	p107	p45	p34	p106	p106	p105	p45	p106	p107	p105	p509	p105	p105	p509	p105	p106	p106	p45	p85	p45	p85
Site	Brun 01	Brun 02	Brun 03	Brun 04	Brun 05	Brun 06	Brun 07	Brun 08	Brun 09	NOW 004A	NOW 005A	NOW 010A	NOW 011A	Salt 01	Salt 02	Salt 03	Salt 04	Salt 05	Salt 06	Salt 07	Salt 08	Salt 09	Salt 10	Salt 11	Salt 15
Juncus mollis	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Juncus usitatus	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kennedia rubicunda	-	-	-	3	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lachnagrostis aemula	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lachnagrostis billardieri subsp. *billardieri*	-	-	-	-	-	-	-	-	-	-	-	3	2	-	-	-	-	-	-	-	-	-	-	-	-
Lachnagrostis filiformis	-	1	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	4	-	-	-	-	-	-	-
Lagenifera gracilis	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Lagenifera stipitata	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
**Lantana camara*	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidosperma laterale	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	1
Leptinella longipes	-	2	3	-	-	-	-	-	-	2	-	-	3	-	-	-	-	-	-	3	-	-	-	-	-
Leucopogon juniperinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Lindsaea linearis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Lobelia anceps	1	1	1	-	-	-	-	-	-	1	-	1	-	-	-	1	1	3	1	-	-	-	-	-	-
Lomandra filiformis subsp. *filiformis*	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Lomandra longifolia	-	-	-	4	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	1	2	-	1
Lomandra multiflora subsp. *multiflora*	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1
**Lonicera japonica*	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsdenia rostrata	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-
Melaleuca decora	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Melaleuca ericifolia	6	4	2	1	6	3	-	-	4	1	1	-	7	1	-	-	-	-	-	1	1	6	-	3	-
Melaleuca linariifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Melaleuca styphelioides	-	-	-	-	-	-	-	-	-	-	4	-	-	1	-	-	4	-	-	-	-	-	-	4	-
Microlaena stipoides var. *stipoides*	-	2	-	2	-	5	4	-	-	-	2	-	-	-	-	-	-	-	2	-	-	2	2	2	2
Notelaea longifolia forma *longifolia*	-	-	-	2	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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Site	Brun 01	Brun 02	Brun 03	Brun 04	Brun 05	Brun 06	Brun 07	Brun 08	Brun 09	NOW 004A	NOW 005A	NOW 010A	NOW 011A	Salt 01	Salt 02	Salt 03	Salt 04	Salt 05	Salt 06	Salt 07	Salt 08	Salt 09	Salt 10	Salt 11	Salt 15
Olearia viscidula	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opercularia aspera	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2
Opercularia hispida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Oplismenus aemulus	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	3	4	-	-	-	-	-	-	-	-
Oplismenus imbecillis	3	3	-	1	-	2	5	-	-	-	4	-	-	-	-	-	-	-	-	-	-	2	-	4	-
Oxalis exilis	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Oxalis perennans	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ozothamnus diosmifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-
Pandorea pandorana	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Panicum simile	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
**Paronychia brasiliana*	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parsonsia straminea	1	-	-	-	-	-	-	-	-	1	4	-	1	1	-	-	2	-	-	-	-	2	1	2	1
**Paspalum dilatatum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Pellaea falcata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	1	-	-	-
**Pennisetum clandestinum*	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Persicaria decipiens	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Persoonia linearis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
**Phalaris aquatica*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
**Phalaris minor*	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phragmites australis	2	-	-	-	-	-	-	-	-	2	-	-	-	5	-	6	-	-	-	-	-	-	-	-	-
Phyllanthus similis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
**Phytolacca octandra*	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-
Pimelea linifolia subsp. *linifolia*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Pittosporum revolutum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Pittosporum undulatum	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
**Plantago lanceolata*	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plectranthus parviflorus	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-

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Site	Brun 01	Brun 02	Brun 03	Brun 04	Brun 05	Brun 06	Brun 07	Brun 08	Brun 09	NOW 004A	NOW 005A	NOW 010A	NOW 011A	Salt 01	Salt 02	Salt 03	Salt 04	Salt 05	Salt 06	Salt 07	Salt 08	Salt 09	Salt 10	Salt 11	Salt 15
Poa meionectes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Poa labillardierei var. *labillardierei*	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Podolobium scandens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
**Polygonum arenastrum*	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polymeria calycina	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Poranthera microphylla	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pratia purpurascens	1	1	-	2	-	3	1	-	-	-	1	-	-	-	-	-	-	1	-	-	-	1	2	2	1
Pteridium esculentum	-	-	-	3	-	1	-	-	-	-	1	-	-	-	-	3	3	-	-	-	-	2	1	-	-
Ranunculus inundatus	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
**Rubus discolor*	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubus parvifolius	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sarcocornia quinqueflora subsp. *quinqueflora*	-	-	-	-	-	-	-	1	-	-	-	-	-	-	4	-	-	4	-	-	3	-	-	-	-
Selliera radicans	2	4	4	-	3	-	-	1	4	-	-	3	-	-	6	-	-	5	-	4	5	-	-	-	-
Senecio hispidulus var. *dissectus*	2	1	-	-	-	-	-	-	-	1	-	-	-	-	-	1	1	-	-	-	-	1	-	2	-
**Senecio madagascariensis*	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Senecio minimus	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-
Senecio prenanthoides	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
**Sida rhombifolia*	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solanum americanum	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
**Solanum nigrum*	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solanum prinophyllum	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
**Solanum pseudocapsicum*	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-
Solanum pungetium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
**Sonchus asper* subsp. *glaucescens*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	-	-	1	-	-	-	-
**Sonchus oleraceus*	1	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-
Spergularia sp. B *sensu* Doust (1990)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-

Community	p107	p105	p509	p85	p107	p45	p34	p106	p106	p105	p45	p106	p107	p105	p509	p105	p105	p509	p105	p106	p106	p45	p85	p45	p85
Site	Brun 01	Brun 02	Brun 03	Brun 04	Brun 05	Brun 06	Brun 07	Brun 08	Brun 09	NOW 004A	NOW 005A	NOW 010A	NOW 011A	Salt 01	Salt 02	Salt 03	Salt 04	Salt 05	Salt 06	Salt 07	Salt 08	Salt 09	Salt 10	Salt 11	Salt 15
**Sporobolus indicus*	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sporobolus virginicus var. *minor*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Syncarpia glomulifera subsp. *glomulifera*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Themeda australis	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
Tricoryne elatior	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Triglochin striatum	-	-	5	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tylophora barbata	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Typha domingensis	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Urtica incisa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Vernonia cinerea var. *cinerea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Veronica plebeia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	2	-	1	-
Viola hederacea	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
**Xanthium occidentale*	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zieria smithii	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-